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Biomechanical, psychosocial and individual risk factors predicting low back functional impairment among furniture distribution employees

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Abstract

Background—Biomechanical, psychosocial and individual risk factors for low back disorder have been studied extensively however few researchers have examined all three risk factors. The objective of this was to develop a low back disorder risk model in furniture distribution workers using biomechanical, psychosocial and individual risk factors.

Methods—This was a prospective study with a six month follow-up time. There were 454 subjects at 9 furniture distribution facilities enrolled in the study. Biomechanical exposure was evaluated using the American Conference of Governmental Industrial Hygienists (2001) lifting threshold limit values for low back injury risk. Psychosocial and individual risk factors were evaluated via questionnaires. Low back health functional status was measured using the lumbar motion monitor. Low back disorder cases were defined as a loss of low back functional performance of −0.14 or more.

Findings—There were 92 cases of meaningful loss in low back functional performance and 185 non cases. A multivariate logistic regression model included baseline functional performance probability, facility, perceived workload, intermediated reach distance number of exertions above threshold limit values, job tenure manual material handling, and age combined to provide a model sensitivity of 68.5% and specificity of 71.9%. Interpretation: The results of this study indicate which biomechanical, individual and psychosocial risk factors are important as well as how much of each risk factor is too much resulting in increased risk of low back disorder among furniture distribution workers.

Keywords

Low back disorder; Psychosocial; Biomechanical; ACGIH

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Conflict of interest statement

The authors certify that we have no financial or personal relationship with other people or organizations that could inappropriately bias this work.

1. Introduction

As we enter the second decade of the 21st century, low back disorders continue to be a costly medical condition. Direct medical costs for low back pain in the United States have been estimated from $12.2 to $90.6 billion per annually (Dagenais et al., 2008). Back pain-specific lost production time costs U.S. employers an estimated $7.4 billion per year among workers 40 to 65 years (Ricci et al.,2006). Thus, preventing occupationally related low back disorders would reduce medical costs as well as improve lost production costs for employers.

Manufacturing has been a traditional source of jobs in much of the United States. Dunning et al. (2010) showed that in one state the manufacturing sector had the highest number of musculoskeletal disorders and 24% of those MSDs were low back injuries. However, the United States has been losing manufacturing jobs during the past decade, but the prevalence of low back disorder continues to increase. Freburger et al. (2009) found that the prevalence of chronic low back pain has increased from 3.9% in 1992 to 10.2% in 2006 in North Carolina. One industry sector that appears to be increasing in the United States is warehousing or distribution. Dunning et al. (2010) showed that the industry sector of transportation, warehousing and utilities had a lower number of MSDs but 32.1% of those injuries were to the low back. The percentage of low back disorder claim was greater in the transportation, warehouse and utilities (32.1%) compared to manufacturing (24%). Thus, more focus is necessary on warehousing or distribution environments in order to control low back disorder risk.

1.1. Risk factors for low back disorders

There are a myriad of low back disorder risk factors (Davis and Heaney, 2000; Ferguson and Marras, 1997). These risk factors are often classified into restrictive categories that include biomechanical, psychosocial and individual risk factors. Each of these “silos” has a vast quantity of literature examining how specific risk factors within the silo relate to the risk of low back disorder.

1.1.1. Biomechanical risk factors—Biomechanical risk factors such as lifting, bending, twisting, pushing/pulling, carrying, heavy physical work, frequency, posture, and vibration have been well established in the literature as risk factors for low back disorders (Bernard, 1997; Chaffin and Park,1973; Frymoyer et al., 1980; Marras et al., 1995; NIOSH, 1981; NRC, 2001). In order to prevent low back disorders due to biomechanical exposures risk factors the American Conference of Governmental Industrial Hygienists (ACGIH) (2001) published threshold limit values (TLV). These limit values were based on the most recent biomechanical, psychophysical and epidemiological literature available (Marras and Hamrick, 2006). Thus, biomechanical risk factors should be quantified and one tool available for quantifying these risk factors would be ACGIH low back TLV guideline.

1.1.2. Psychosocial risk factors—Psychosocial risk factors may affect a workers’ psychological response to their work and influence the risk of low back disorders. For example, mental workload was associated with the risk of low back pain symptoms (Johansson and Rubenowitz, 1994; Theorell et al., 1991). Linton (2005) found that increased workload more than doubled the odds of low back disorder. Job satisfaction has been associated with low back disorder (Bergenudd and Nilsson, 1988; Davis and Heaney, 2000; Magora, 1973; Symonds et al., 1996; Vallfors, 1985; Violante et al., 2005). Low co-worker support has been shown to increase the risk of low back disorder four-fold among cosmetologists (Tsigonia et al., 2009). Job stress has also been associated with increased incidence of low back disorders (Davis and Heaney, 2000; Ferguson and Marras, 1997;

Mehrdad et al., 2010). Marras et al. (2000) found that in depending on personality type, psychosocially stressful environments lead to increased muscle coactivity, which increased spine loading and risk of low back disorder. Ferguson and Marras (1997) in a review concluded that as low back disorders progress toward disability, the psychosocial risk factors played a more prominent role. Thus, the psychosocial risk factor silo represents an important and complex risk factor for occupationally related low back disorders.

1.1.3. Individual risk factors—Individual or personal risk factors such as age, gender, smoking, previous history of low back pain, race and year of experience on the job have long been established as risk factors for low back disorders (Andersson, 1981; Ferguson and Marras, 1997; Frymoyer et al., 1980; NRC, 2001; Troup et al., 1981). In a review of the epidemiologic aspects of low back pain in industry Andersson (1981) stated that the maximum frequency of symptoms occurs between the ages of 35 and 55. Bigos et al. (1986) found that workers between 31 and 40 years of age were most susceptible to high-cost back injuries. Age variations in the literature, may be created by the cut-points in age categories as well as the definitions of low back pain or cases of lost time due to low back pain. Contradictions appear in the literature with the gender factor as well, Bigos et al. (1986) found that women had fewer injuries than men whereas Andersson (1981) suggested no differences in the rates of back pain between men and women. Troup et al. (1981) found among workers with occupationally related low back pain 50% had recurrent symptoms within the first year. Bigos et al. (1986) found that newer employees tended to have a higher risk of back injury. Thus, a multitude of individual risk factors have been associated with increased risk of low back disorder risk in the literature, therefore these risk factors should be considered when predicting the risk of low back disorders.

1.2. Research goal

This brief review illustrates the multitude of risk factors within each silo that may influence low back disorder risk. Marras (2005) suggested that research has progressed within each category or “silo” yet few research studies have examined multiple “silos”. It is hypothesized that each of the “silos” contributes to the overall risk of low back disorder. Consequently, the goal of this research study was to quantify three risk factors “silos” biomechanical, psychosocial and individual in furniture distribution centers and develop a predictive model for the risk of low back disorders using factors from each of the three “silos”.

2. Methods

2.1. Approach

This was a prospective study with a 6 month follow-up time. Biomechanical, psychosocial and individual risk factors as well as low back health status were measured at baseline. Low back health status was measured at a six month follow-up. A clinically meaningful loss in low back function was selected as the outcome measure over traditional measures of symptoms or lost time because it provided an objective measurement of outcome instead of a subjective measure (Ferguson et al., 2005). A multivariate logistic regression model was developed to predict which workers had a clinically meaningful loss in low back functional performance during the six months.

2.2. Participants

Four hundred and fifty-four employees at 9 furniture distribution facilities were enrolled in the study at baseline. Follow-up data was collected on 307 employees. Thus, 68% of the baseline population had follow-up data.

2.3. Study design

This was a prospective study with a six month follow-up time. Low back disorder risk factors were classified into individual, psychosocial, and biomechanical. Psychosocial and individual risk factors were assessed via questionnaire. Furniture distribution jobs are highly variable and the ACGIH TLV provided an effective evaluation tool for these types of jobs. Thus, biomechanical risk factors were evaluated relative to the ACGIH TLV lifting guidelines.

2.4. Instrumentation

The lumbar motion monitor (LMM) was used to measure low back health status (functional performance probability) (Marras et al., 1999). The LMM was placed on the subject with a belt and shoulder harness. The LMM signal was transmitted to a laptop computer, where it was stored for further analysis.

Several basic pieces of equipment were used to assess workplace risk factors against the threshold limit values determined by the American Conference of Governmental Industrial Hygienists (ACGIH) (2001). These included a heavy duty scale to weigh pieces lifted or carried, a Chatillon® force gauge was used to measure pushing and pulling, and a tape measure.

2.4.1. Psychosocial questionnaire—The National Institute of Occupational Safety and Health Generic Job Stress Questionnaire was used to measure perceived workload, role conflict, role ambiguity, social support and job satisfaction (Hurrell and McLaney, 1988). Three measures of organizational fairness were evaluated with a questionnaire developed based on Heaney and Joarder (1999). The General Health Questionnaire was used to evaluate psychological well-being (Goldberg and Williams, 1988).

2.5. Testing procedure

Employees in groups of 3 to 6 workers entered a conference room where the study was explained. After the study was explained, workers signed the university's IRB consent forms prior to completing the questionnaire. The questionnaire required 30 to 35 min to complete. As workers were completing the self-administered questionnaire, individuals were taken to another room to complete the low back functional performance tasks.

2.5.1. Functional performance—The appropriate size LMM was placed on the subject. The subject was instructed to stand with their feet shoulder with apart and cross their arms in front of them. A total of six functional performance exertions were performed. All the instructions were to move as fast as you can comfortably. The first task was a controlled sagittal flexion extension task, where subjects flexed and extended, while maintaining a zero twist position (±2°). The twisting position was displayed on the computer screen. The next two tasks were to twist as far as comfortably possible clockwise and counter clockwise with visual feedback. The last three tasks were randomly performed with no visual feedback. The subjects were instructed to bend side to side, flexion and extended and twist repeatedly for eight seconds. The LMM testing was performed in a private room away from other data collection. The testing required approximately 10 min.

2.5.2. Workplace risk assessment—A Certified Professional Ergonomist performed the workplace evaluations on all the jobs. On each job the frequency (number of time per hour that the job required a physical exertion), duration (amount of the work day physical exertions were performed), force, horizontal distance during force application, and vertical location during force application were assessed.

2.5.3. Follow-up session—A follow-up testing session was completed 6-months after the initial session. At the follow-up session the workers completed the same questionnaire and low back functional performance evaluation was completed with the LMM.

2.6. Data analysis

2.6.1. Functional performance—The functional performance probability of low back health function was calculated using custom software (Ferguson and Marras, 2004; Marras et al., 1999). The functional performance probability combined range of motion, velocity and acceleration into one score from 0.0 to 1.0. The change in the functional performance probability between the initial evaluation and the follow-up evaluation was calculated.Ferguson et al. (2009) has defined a meaningful change in functional performance probability as greater than 0.14 therefore, a case was defined as a decrease in function of < −0.14. Workers with a change in functional performance probability of >−0.14 were classified as non-cases. Workers with a baseline functional performance probability of <0.14 were deleted from the data.

2.6.2. Workplace assessment—The overall number of exertions per hour for each job, number of exertions per hour above the threshold limit value as well as the percentage of exertions above the threshold limit value was calculated for each job. The data was also broken into four vertical regions including floor to mid shin, mid shin to knuckle height, knuckle height to shoulder height and overhead to 8 cm below the shoulder. The data was also broken into three horizontal reach distances of close <30 cm, intermediate 30–60 cm and far 60–80 cm. All the horizontal reach distances were measured from the mid-point between the inner ankle bones. Finally combinations of the vertical and horizontal regions were created. In order to publish a reasonable amount of physical measures only number of exertions and percentage of exertions above TLV were presented.

2.7. Statistical analysis

T-tests were completed between the cases and non cases for individual, psychosocial and biomechanical risk factors Tables 1-3, respectively using SAS 9.2 (SAS Institute, 1990). Classification and regression tree (CART) software was used to dichotomize each risk factor (Breiman et al., 1984; Steinberg and Colla, 1995). Univariate logistic regression was run on dichotomized risk factors to provide in-sight for multivariate model development. A multivariate logistic regression model was developed to predict low back functional impairment using the all three categories of risk factors.

3. Results

Ninety-two workers had a clinically meaningful decrease in low back functional performance (i.e. cases). One hundred and eighty-five workers were non-cases. Thirty workers were deleted with a baseline functional performance probability of b0.14, which was considered too impaired to participate in the study. Thus, cases were clearly defined as having a clinically meaningful decrease in low back function performance (Ferguson et al., 2009).

Table 1 lists the means and p-values from t-test for individual factors. The table indicates that the functional performance probability was significantly greater at baseline in the cases compared to non cases, indicating that workers who became cases had a better low back functional performance score at baseline compared to the non cases. The age factor was significantly different with cases being older than non cases. The job tenure manual material handling was significantly longer in the cases (159 months) compared to the non cases (109 months). The univariate CART analysis of the individual risk factors revealed some interesting findings. The CART analysis split the job tenure manual material handling factor at 258 months. A follow-up logistic regression analysis showed that those workers with more than 258 months of experience were 3.6 times more likely to have a meaningful loss in functional performance probability with a 95% confidence interval of 1.74 to 7.27. The CART analysis split the age factor at 40.5 years. The logistic regression analysis indicated individuals older than 40.5 years were 2.5 times more likely to have a loss in low back functional performance compared to younger workers. The CART analysis split the baseline functional performance probability at 0.65. The logistic regression analysis had an odds ratio of 3.23 with a 95% confidence interval of 1.91 to 5.36.

Table 2 lists the means and standard deviations for the psychosocial variables for the cases and non cases as well as p-values. The table indicates that none of the psychosocial factors were significantly different between the cases and non cases. The univariate CART analysis of these data revealed a very interesting finding for the perceived workload variable. The CART results revealed multiple cut-points where a perceived workload less the 2.71 indicated higher risk as well as a workload greater than 3.6. The univariate logistic regression odds ratio for perceived workload split based on the CART category was 2.36 with a 95% confidence interval from 1.4 to 3.96. Thus workers with a perceived workload less than 2.71 or greater than 3.6 were more than twice as likely to have a loss in low back functional performance probability.

Table 3 lists the means and standard deviations for the physical variables as well as p-values indicating statistically significant differences between the cases and non cases. The number of exertion and percentage of exertions above TLV are presented in Table 3. In order to have a reasonably size table the number of exertion above the TLV was eliminated from the table. Only 3 of the 40 variables showed statistically significant differences between the cases and non cases. However, these differences were in the opposite direction than expected where the non cases had greater exposure than the cases. The univariate CART results were more interesting. Of particular interest was the intermediate number of exertions, which split in CART at 282 exertions per hours. The univariate logistic regression result indicated workers with more than 282 exertions per hour had an odds ratio of 10.6 with a 95% confidence interval from 1.22 to 91.77. Thus, workers that had more than 282 exertions per hour in the intermediate reach region were more than 10 times more likely to have a meaningful loss in low back function compared to those with less than 282 exertions per hour. Thus, the CART analysis indicated which biomechanical variable was important as well as how much was too much.

3.1. Multivariate model predicting low back functional impairment

The multivariate logistic regression model that best predicted cases and non cases is shown in Table 4. The multivariate model included four baseline individual variables functional performance probability, job tenure manual material handling, age, and facility. Facility was trichotomized into three levels of low, medium and high risk from the CART results. The physical variable intermediate reach distance number of exertions per hour above the TLV and a psychosocial perceived workload variable. This combination of variables resulted in a sensitivity of 68.5% and specificity of 71.9%. The cut-points in the table provide a threshold above or below which the variable becomes critical in creating risk.

4. Discussion

This was one of only two studies to quantify a low back disorder case as a meaningful loss in low back functional performance (Ferguson et al., 2009; Marras et al., 2010). This outcome measure was selected because it provided an objective quantitative measure for a case as oppose to the often used subjective measure of pain symptoms to define a low back injury case. The definition of a case is an important aspect of a research study because it will influence the number of cases as illustrated in the baseline prevalence of low back disorders in the current study (Ferguson et al., 2008). Furthermore, the risk factors that may be shown to be predictive of low back disorder cases are influenced by the definition of a case (Ferguson and Marras, 1997; Marras et al., 2007).

This was the first research study to use the ACGIH TLV (2001) to quantify exposure for low back disorder risk. It is interesting to note that Table 3 shows that number of exertions from the floor was significantly larger in the non cases compared to the cases however the number of exertions in the floor region was small in both cases and non cases compared to the overall number of exertions. Thus, this may show that from an ergonomic point of view the most basic concepts of keeping items up off the floor in order to avoid bending more than 30° have been implemented in most of the furniture distribution facilities visited for this study.

The univariate results of intermediate reach distance number of exertions per hour greater than 282 causing a worker to be at 10 times greater risk of a meaningful loss in low back function is quite interesting from a biomechanical perspective. The intermediate distance was a moment arm of 30 cm to 60 cm. The increased risk when the number of exertions in this region exceeds 282 may illustrate the importance of the moment arm and subsequent moment in determining the risk of low back disorders. The moment arm has been an established risk factor for low back disorder risk and was in-corporated in the National Institute of Occupational Safety and Health (NIOSH, 1981) Lifting Guide thus these results illustrated the continued importance of moment arm in the risk for low back disorder. The threshold of 282 exertions per hour creating increased risk may indicate that fatigue would play a role in low back disorder risk. Fatigue has been suggested as a risk factor for low back injury by several researchers (Gorelick et al., 2003; Kumar, 2001). If fatigue is a potential risk factor then the amount of rest time between exertions may play an important role in the risk of low back disorders. Lavender et al. (2011) recently found shorter rest time increased the risk of reporting a low back injury.

Marras (2008) has suggested a “J-shaped” relationship between risk of low back disorder and physical work load. Where sedentary jobs with low physical demand have a moderate risk of low back pain, moderate exposure to physical demand jobs have the lowest risk and heavy physical demand jobs have the high risk. The psychosocial measure of perceived workload may potentially have a “J-shaped” or “U-shaped” association with risk. The cut-points indicate that perceived workload less than 2.71 had an increased risk and workload greater than 3.6 have an increased risk. Thus, a perceived workload that was too low created an elevated risk and a perceived work load that was too high created an increased risk of low back disorder. A perceived workload score of 3.0 would be optimal resulting in reduced risk of low back disorder. There would be probably little argument that a high perceived workload would increase the risk of low back disorder furthermore these findings correspond with those findings of Linton (2005). However, the low perceived workload having increased risk of low back disorder may cause some to question how that would be possible. A low perceived workload may cause workers not to take the appropriate safety measures when performing manual material handling tasks which may result in increased risk of low back disorder. Sofie et al. (2003) examined the perceptions of nursing assistants in health care facilities and found that the behavior of the workers was influenced by their perception of risk of injury. Stewart-Taylor and Cherri (1998) conducted a more thorough investigation of asbestos workers and workers who perceived a greater risk of illness were more likely to use protective equipment, thus reducing exposure. While risk of injury to the low back is not the same as chemical exposure, a workers perception of injury risk may still influence behavior and use of tools to reduce the risk of low back disorder.

The six variable model presented in Table 4 showed one combination of variables that had a sensitivity and specificity of nearly 70%. The biomechanical and psychosocial risk factor “silos” are both represented in the model predicting a meaningful loss in low back function. The biomechanical variable knuckle to shoulder intermediate reach distance number of exertions above the TLV was substituted in the model in Table 4 for the physical variable and the same sensitivity and specificity resulted. The cut-point was 126 exertions per hour in that region compared to 129 exertions per hour in the intermediate reach distance. Furthermore, the physical factor of far number of exertion per hour could be substituted in the model and resulted in only a slightly higher AIC score. The final model was selected based on the lowest AIC score from all the models developed. Thus, the model in Table 4 is not the only model with good sensitivity and specificity however all models with good sensitivity and specificity contained at least one psychosocial variable, physical variable and individual variable. The model in Table 4 is predicting a loss in low back functional performance, which is hypothesized to precede low back pain symptoms in a theoretical model of cascading events leading to disability (Ferguson and Marras, 1997). Finally, it should be noted that changing the outcome measure to symptoms or disability would most likely change the risk factors entering into the final model (Marras et al., 2007).

The results of this study illustrate the differences in results among various statistical methods. The t-tests provide descriptive statistics but found few statistical differences, which may lead one to think there were no differences between cases and non-cases. The CART analysis provided the research team with an indication of which variables might be of greater potential for distinguishing between the two groups. The CART analysis also provided threshold values to dichotomize or trichotomize continuous data variables. Thus the final model had variables from each of the “silos” and it also indicated how much of each variable was too much resulting in increased risk of low back disorder.

4.1. Limitations

This was a prospective study with a follow-up time of only 6 months. This was a relatively short follow-up time for a prospective study. However, given the high turnover rates in these jobs this short follow-up time seemed prudent. A second limitation may be measurement bias where not all risk factors are measured to the same level or degree. Third, the meaningful change in low back function may be influenced by non work-related risk factors not assessed in the study. Finally, inferences of this study apply only to cases and non-cases and not to those individuals with non-meaningful decreases in functional performance probability.

5. Conclusions

The classification and regression tree software cut-points provide an indication of how much exposure is too much exposure for each risk factor in the model. Quantifying a meaningful loss in low back functional performance provides an objective measure for a low back disorder case. The risk of a meaningful loss in low back performance was predicted by a combination of biomechanical, psychosocial and individual risk factors with a sensitivity of 68.5% and specificity of 71.9%.

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Table 1

Descriptive statistics for individual risk factors for cases and non cases.

Variable name	Non cases N = 185		Cases N= 92		*P*-values
	Mean	St. dev	Mean	St. dev.	
Age (years)	35.14	11.57	38.85	11.42	0.0121[a]
Height (cm.)	178.51	8.95	175.43	9.77	0.0103[a]
Weight (kg.)	87.57	19.97	84.68	16.45	0.2052
Gender (percentage males)	0.94	0.24	0.92	0.27	0.5985
Job tenure company (months)	51.41	57.07	59.49	59.45	0.2807
Job tenure job (months)	44.51	54.55	46.66	53.72	0.7595
Job tenure manual material handling (months)	109.31	111.23	159.53	149.28	0.0061[a]
Smoking (percent smokers)	0.35	0.48	0.32	0.47	0.5698
Baseline functional performance probability	0.55	0.24	0.69	0.20	0.0001[a]

[a]Indicates statistically significant differences at alpha = 0.05.

Table 2

Descriptive statistics for psychosocial risk factors both cases and non cases.

Variable name	Non cases N = 185		Cases N= 92		*P*-values
	Mean	St. dev	Mean	St. dev	
Workl oad	3.32	0.73	3.26	0.80	0.5276
Role conflict	2.31	0.68	2.39	0.75	0.3899
Role ambiguity	2.02	0.72	2.14	0.76	0.1891
Mental demand	3.56	0.63	3.59	0.65	0.7218
Job insecurity	1.93	0.89	2.13	0.92	0.0748
Job control	3.15	0.80	3.27	0.77	0.2580
Social support boss	2.88	0.75	2.88	0.85	0.9934
Social support coworkers	2.95	0.61	2.98	0.59	0.7230
Unfairness boss	2.49	0.80	2.35	0.83	0.1866
Unfairness management	2.67	0.75	2.74	0.92	0.5401
Job satisfaction	1.63	0.28	4.03	0.95	0.3970
Job strain	1.39	0.89	1.59	0.30	0.1478

[a] Indicates statistically significant differences at alpha = 0.05.

Table 3

Descriptive statistics for biomechanics! risk factors both cases and non cases.

Variable name	Non cases N = 185		Cases N= 92		*P*-values
	Mean	St. dev	Mean	St. dev	
Overall number of exertions	123.53	132.95	131.63	137.92	0.6373
Overall percentage of exertions above TLV	48.90	28.90	52.01	27.18	0.3899
Horizontal distance (moment arm)					
Close number of exertions	30.96	30.91	33.02	33.65	0.6138
Close percentage of exertions above TLV	20.71	23.09	19.11	23.38	0.5902
Intermediate number of exertions	67.32	73.59	71.48	71.08	0.6588
Intermediate percentage of exertions above TLV	49.44	29.31	52.80	27.17	0.3590
Far number of exertions	25.21	30.56	27.20	33.86	0.6245
Far percentage of exertions above TLV	59.10	40.32	61.78	40.12	0.6020
Vertical height					
Shoulder number of exertions	5.91	14.53	4.65	8.53	0.3644
Shoulder percentage of exertions above TLV	40.72	48.40	39.13	47.56	0.7957
Knuckle to shoulder number of exertions	91.04	103.22	107.98	135.52	0.2926
Knuckle to shoulder percentage of exertion above TLV	40.11	30.07	42.63	29.70	0.5097
Mid-shin number of exertions	16.97	71.09	8.97	10.64	0.1795
Mid-shin percentage of exertion above TLV	51.81	40.06	58.78	42.03	0.1806
Floor number of exertion	7.41	18.83	4.02	6.85	0.0304[a]
Floor percentage of exertions above TLV	44.32	49.81	42.39	49.69	0.7610
Combine vertical height and horizontal reach					
Shoulder close number of exertions	1.69	3.80	1.28	2.11	0.2565
Shoulder close percentage above TLV	16.97	32.87	12.61	25.44	0.2254
Shoulder Intermediate number of exertions	3.19	7.57	2.60	4.58	0.4187
Shoulder Intermediate percentage above TLV	35.41	46.95	40.22	47.60	0.4246
Shoulder far number of exertions	1.06	3.46	0.81	2.04	0.5208
Shoulder far percentage of exertions above TLV	22.70	42.00	20.65	40.70	0.6994
Knuckle to shoulder close number of exertions	23.88	26.76	28.66	34.52	0.2467
Knuckle to shoulder close percentage above TLV	14.26	20.24	15.04	21.45	0.7657
Knuckle to shoulder intermediate number of exertions	50.09	54.98	60.73	72.38	0.2159
Knuckle to shoulder intermediate percentage above TLV	40.84	30.04	41.06	30.19	0.9537
Knuckle to shoulder far number of exertions	20.01	25.90	24.48	34.22	0.2708
Knuckle to shoulder far percentage above TLV	52.22	43.12	54.21	43.88	0.7192
Mid-shin close number of exertions	3.52	12.47	2.07	3.02	0.1351
Mid-shin close percentage above TLV	18.17	32.69	15.29	31.05	0.4824
Mid-shin intermediate number of exertions	9.89	46.65	5.62	5.56	0.2212
Mid-shin intermediate percentage above TLV	52.33	39.61	57.35	42.04	0.3314
Mid-shin far number of exertions	2.70	12.29	1.29	2.33	0.1342
Mid-shin far percentage above TLV	23.20	40.26	18.36	36.51	0.3328
Floor close number of exertions	1.87	4.73	0.97	1.62	0.0208[a]

Variable name	**Non cases N = 185**		**Cases N= 92**		***P*-values**
	Mean	**St. dev**	**Mean**	**St. dev**	
Floor close percentage above TLV	23.83	42.22	20.79	39.63	0.5653
Floor intermediate number of exertions	3.85	8.85	2.51	4.50	0.0965
Floor intermediate percentage above TLV	44.86	49.87	43.48	49.84	0.8276
Floor far number of exertions	1.46	4.44	0.57	1.13	0.0114[a]
Floor far percentage above TLV	30.27	46.07	29.35	45.79	0.3890

[a]Indicates statistically significant differences at alpha = 0.05.

Table 4

Multivariate logistic regression model predicting functional impairment.

Variable name	Cut-point	Estimate	St. error	Wald score	Odds ratio	95% confidence interval	
Intercept		− 3.21					
Baseline functional performance probability	> 0.65	1.18	0.29	16.43	3.26	1.84	5.78
Facility	Low, medium, high	0.74	0.28	6.87	2.08	1.20	3.61
Perceived workload	<2.71 or > 3.6	0.87	0.29	8.89	2.39	1.35	4.24
Intermediate reach number of exertion above TLV	> 129	1.57	0.72	4.72	4.79	1.16	19.71
Job tenure manual material handling	> 258	0.94	0.46	4.11	2.55	1.03	6.31
Age	> 40.5	0.81	0.35	5.42	2.25	1.14	4.47